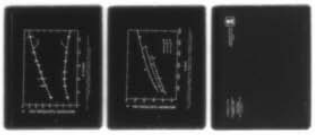
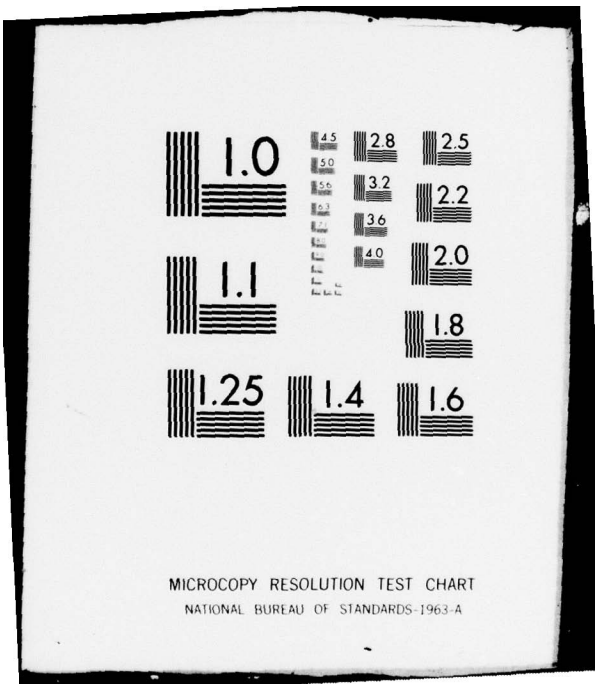
AD-A062 102 NAVAL RESEARCH LAB WASHINGTON D C F/G 20/9
SECONDARY ELECTRON EMISSION BY ENERGETIC IONS INCIDENT ON METAL--ETC(U)
AUG 78 R DECOSTE, B H RIPIN

UNCLASSIFIED NRL-MR-3814 NL

| OF |
AD
A062102



END
DATE
FILMED
3-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NRL Memorandum Report 3814

Secondary Electron Emission by Energetic Ions Incident on Metal Surfaces

R. DECOSTE

Laser Plasma Branch
Plasma Physics Division
and
University of Maryland

and

B. H. RIPIN

Laser Plasma Branch
Plasma Physics Division

August 1978

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NRL Memorandum Report 3814	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: NRL-MR-3814	
4. TITLE (and Subtitle): SECONDARY ELECTRON EMISSION BY ENERGETIC IONS INCIDENT ON METAL SURFACES	5. TYPE OF REPORT & PERIOD COVERED: Interim report on a continuing NRL problem.
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): R. Decoste* and B.H. Ripin	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Research Laboratory, Washington, D.C. 20375	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NRL Problem H02-29A
11. CONTROLLING OFFICE NAME AND ADDRESS: Department of Energy, Washington, D.C. 20545	12. REPORT DATE: August 1978
	13. NUMBER OF PAGES: 14
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*Now with Sachs-Freeman Associates, Bladensburg, MD.

Work performed at the Naval Research Laboratory under the auspices of the Department of Energy.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Secondary electron emission
Secondary electron suppression
Ion analyzer
Charge collector

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An experimental technique, especially well adapted to measure secondary electron coefficients for energetic ions incident on any charge collector surface, is described. The technique uses a laser-produced plasma as an ion source, a high-energy ion analyzer as an ion energy and species filter and a tubular electrode arrangement to suppress or attract the secondary electrons at the charge collectors. The secondary electron coefficients for several ionization states of carbon and hydrogen ions incident on copper surfaces are given as a function of incident ion energy between 15 and 150 keV/Z.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECONDARY ELECTRON EMISSION BY ENERGETIC IONS INCIDENT ON METAL SURFACES

INTRODUCTION

Charge collectors are simple devices extensively used as a general diagnostic for laser-produced plasma. The collectors are used either to measure directly the expanding ion current a known distance away from the target or as ion detectors for ion analyzers. However, for each ion striking a charge collector, a number γ of secondary electrons are emitted. The number of such secondaries is a function of the mass, velocity and charge of the incident ion. Usually, a potential is applied to the collector in order to repel the secondary electrons to the electrical ground. If quantitative information is desired from the collector data, subtraction of the secondary electron emission from the collector signal is therefore required.

In the case of high energy ions (> 10 keV/Z, where Z is the ion charge state), the contribution of the secondary electron current to the charge collector signal is typically higher than the ion current, i.e., $\gamma > Z$. In this paper we describe an experimental technique which is well adapted to measure secondary electron coefficients for energetic ions ($\gamma > Z$) incident on any collector surface. The technique uses a laser-produced plasma as an ion source, a high-energy ion analyzer as an

Note: Manuscript submitted June 23, 1978.

energy and species filter and a tube arrangement to repel or attract the secondary electrons at the charge collectors. The advantages of using this tube arrangement for suppression of secondary electrons in a charge collector are also discussed. Since plastic targets (CH_n) are extensively used in laser-plasma interactions, the secondary electron coefficients for carbon and hydrogen ions incident on copper surfaces are given as a function of incident ion energy between 15 and 150 keV/Z.

SECONDARY ELECTRON EJECTION

There are two principle mechanisms which cause the ejection of electrons when particles strike solid surfaces: potential[1] and kinetic[2] emission. Potential emission occurs if the potential energy of the bombarding particles is higher than the work function of the metal. In this case the electron ejection is exclusively a consequence of the potential energy transfer of the bombarding particles to the metal. Thus, potential emission should be independent of the kinetic energy of the bombarding particles but strongly dependent on the charge state of the incident ions. The other mechanism which can produce an ejection of electrons is kinetic emission. In this case a part of the kinetic energy of the bombarding particle is transferred to target electrons (of which a fraction can leave the solid). The kinetic emission should therefore be independent of the charge state of the incident ion.

For energetic ions, the contribution to the secondary electrons emitted due to potential emission becomes small relative to the kinetic emission mechanism. The secondary electron coefficient γ is therefore expected to be fairly independent of the charge state of the incident

ions in the high energy range of interest. The atomic mass of the impinging ion at a given energy is, however, expected to affect γ since the ion penetration depth into the material is mass dependent.

A parameter which can strongly affect the secondary coefficient γ is the cleanliness of the charge collector surface. It has been shown experimentally[3] that "gassy" collector surfaces can produce up to 5 times more secondary electrons than atomically clean surfaces. Measurements of γ for a specific collector surface should therefore be extrapolated to other collectors only if the experimental conditions and collector material are similar to the calibrated collector.

EXPERIMENTAL TECHNIQUE

Most measurements of secondary electron coefficients presented in the literature have been done with an experimental arrangement similar to that shown schematically in Fig. 1a. In all cases, a single-species monoenergetic ion beam is assumed to be incident on the entrance aperture. The collector current I_c is due to both the incident ions and emitted secondary electrons, whereas the tube current, I_e, is due to the collected secondary electrons only. In order to make sure that the secondary electrons produced from the edge of the entrance aperture cannot be collected by the tube, a suppressor with a high negative bias voltage is used between the entrance aperture and the tube. The secondary electron coefficient γ is related to the ratio I_c/I_e by the equation

$$\gamma = Z \left[\frac{I_c}{I_e} - 1 \right]^{-1}, \qquad (1)$$

where Z is the charge of the incident ion. For the case of energetic ions on gassy collector surfaces, we have $\gamma > Z$ and therefore $I_c/I_e \sim 1$. A small uncertainty in I_c or I_e can therefore lead to a large error in the determination of γ.

In order to facilitate and improve the accuracy of the measurement, the technique shown in Fig. 1b was developed. A uniform density ion beam is again assumed to be incident on the entrance aperture. One tube is biased positively in order to attract secondary electron while the other tube is biased negatively to repel secondary electrons back to the ion collector. The collector current I_i associated with the negatively biased tube is therefore due solely to the ion current. The secondary electron coefficient γ is then given by

$$\gamma = Z \left[\frac{I_c}{I_i} - 1 \right] . \qquad (2)$$

For $\gamma > Z$, the subtraction error of large comparable numbers can be avoided in Eq. (2) since $I_c \gg I_i$. For high energy ions incident on gassy collector surfaces this technique is therefore preferred.

In principle, the biased tubes in Fig. 1b could be replaced by properly biased highly transparent fine meshes.[4] In practice, however, a negatively biased mesh, due to its finite cross section, can itself produce secondary electrons which can be accelerated back to the ion collector and contribute to the ion current. The advantage of the tubular electrode is to supply the suppression potential without physically intercepting the ions. This technique of using a negatively biased tube in front of a particle collector has also been successfully

used in the design of an electrostatic electron analyzer[5] and an ion charge collector.[6]

It was mentioned above that the ion beam incident on the collector arrangement shown in Fig. 1b should be monoenergetic, uniform and contain a single ion species. An excellent energetic ion source which can meet these requirements is a laser-produced plasma coupled with a high energy ion analyzer as an ion species and energy filter. The experimental arrangement is shown schematically in Fig. 2 a and b. The ions are produced by intense Nd-laser irradiation (10^{16} W/cm^2 at 1.06 μm for 75 psec) of a solid target.[7,8] Since the half-energy focal spot diameter of the focused laser beam (~ 25 μm), which is characteristic of the ion source dimensions, is much smaller than the ion flight distance between the target and the entrance slit of the analyzer, a well collimated ion beam is propagating beyond the entrance slit of the analyzer. The electrostatic high-energy ion analyzer is of the same type as the one described in Ref. 8 and 9, except that the distance between the end of the deflection plates and the exit slit plane has been reduced to 6 cm. The beam expansion due to space charge forces within the analyzer is therefore highly reduced and a larger entrance slit can be used.

The exit slit arrangement of the analyzer is shown in Fig. 2b. Each exit slit location from the analyzer axis corresponds to a single ion energy E divided by the charge Z. For a given E/Z, the ion species (atomic mass divided by the charge) can be determined from the analyzer parameters or, alternatively, from the ion time-of-flight between the target and the charge collector. Only two E/Z channels were used on

each laser shot, both with an energy and species resolution of 10%. Each E/Z channel consists of two exit slits with a tube followed by a collector behind each slit. The cross section of each rectangular tube is at least twice that of the corresponding slit and the tube width to length ratio is typically 2.5 to 1. The upper and lower tube of each E/Z channel are usually biased at +300V and -300V respectively. Each collector, mounted individually behind the tubes, is connected to a wide-band amplifier and is time-resolved with a fast oscilloscope.

The use of Eq. (2) to obtain secondary coefficients assumes that the incident ion current is the same for both slits at a particular E/Z. This assumption was verified experimentally be comparing the output signals from the collectors associated with the two slits at the same E/Z. The two collector signals, with the same bias voltage on their tube, were found to be equal on the average, with a shot-to-shot deviation of up to ± 10%. This means that the entrance slit height is well aligned with respect to the exit slit arrangement, and that the plasma density over the entrance slit height is uniform to within 10%. This plasma nonuniformity on the entrance slit is mostly observed at high target irradiance and is responsible for some of the scatter in the data observed during the measurement of the secondary electron coefficients.

SECONDARY ELECTRON COEFFICIENTS

The collectors used for the measurements of γ are made of copper bonded to printed circuit boards. Since the collector surfaces are simply cleaned with acetone at room temperature before being mounted,

they can be categorized as "gassy" surfaces, in contrast with "atomically cleaned" surfaces.

The secondary electron emission coefficients for C^{+6} and H^+ ions incident on the copper collectors are shown in Fig. 3 as a function of ion energy. The curves are simply smooth fits through the points. Each point and its associated standard deviation represents an average of 5 measurements of γ using Eq. (2). As mentioned in the previous section, the scatter in the data points is due mostly to some nonuniformity of the ion current incident on the two collectors at the same E/Z. For the H^+ results in Fig. 3, the secondary coefficient γ for our gassy surfaces is typically three times higher than those reported for atomically cleaned surfaces.[3]

Figure 4 shows the influence of the charge state of the incident carbon ions on the secondary coefficient using our copper collectors. Each point is an average of 5 data points with a typical standard deviation of ± 10% (not shown in Fig. 4). One notices that the difference $\Delta\gamma = \gamma(C^{z+}) - \gamma(C^{(z-1)+})$ is nearly independent of the kinetic energy of the ions. This is not surprising since the difference $\Delta\gamma$ is due to secondary electrons emitted by the potential emission mechanism discussed above. Since the incident ion kinetic energy is much higher than the ion potential energy, the kinetic emission mechanism dominates the potential emission. For energetic carbon ions (> 100 keV) the secondary electron coefficient γ is, therefore, fairly independent of the incident ions, as predicted above.

REFERENCES

1. M. Kaminsky, "Atomic and Ionic Impact Phenomena on Metal Surfaces", Academic Press Inc., New York (1965)

2. K.H. Krebs, Fortschritte der Physik 16, 419 (1968)

3. L.N. Large and W.S. Whitlock, Proc. Phys. Soc., 79, 148 (1962)

4. J.S. Pearlman, Rev. Sci. Instrum., 48, 1064 (1977)

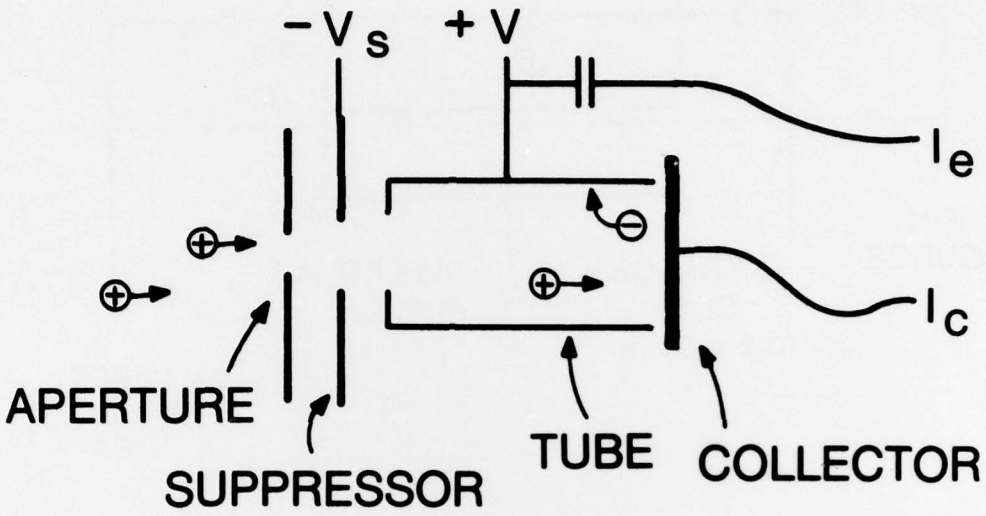
5. B.H. Ripin, Univ. of Maryland Techn. Report 71-038 (1970),

6. B.H. Ripin and R. Decoste, NRL Memo Report 3494 (May, 1977), unpublished

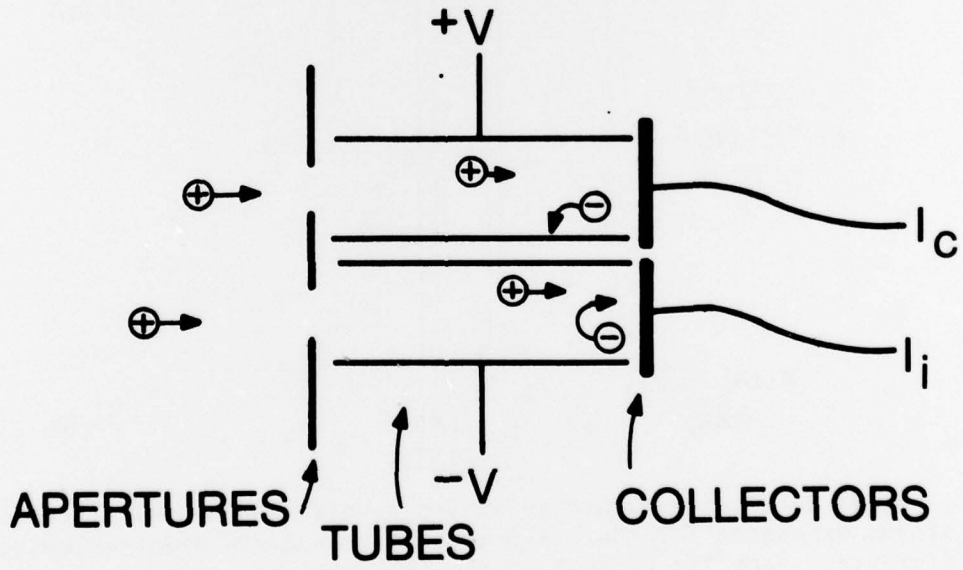
7. R. Decoste and B.H. Ripin, Phys. Rev. Lett., 40, 34 (1978)

8. R. Decoste, NRL Memo Report 3774, (April 1978), unpublished

9. R. Decoste and B.H. Ripin, Rev. Sci. Instrum., 48, 232 (1977)



(a)



(b)

Fig. 1 - Schematic of experimental arrangements for the measurement of secondary electron coefficients. A monoenergetic, uniform and single-species ion beam is assumed to be incident on the apertures in both cases. The arrangement in (b) becomes more accurate than the one in (a) when $\gamma > Z$.

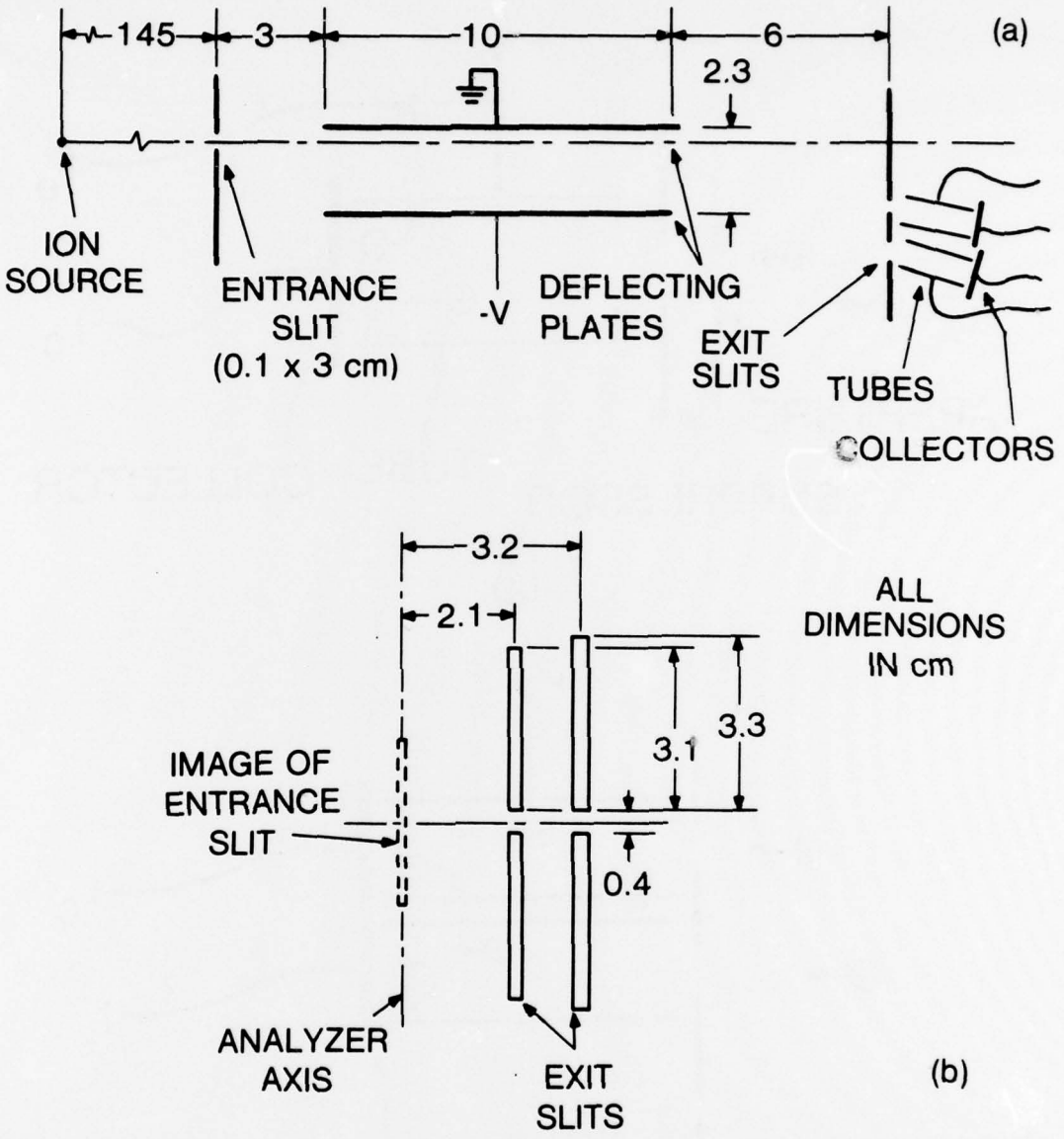


Fig. 2 - (a) Ion analyzer used as an ion species and energy filter of the plasma expansion for the measurement of secondary electron emission coefficients. Each E/Z channel of the analyzer consists of two exit slits with a tube followed by a collector behind each slit as shown in Fig. 1b. (b) Entrance and collection slit arrangement in the analyzer.

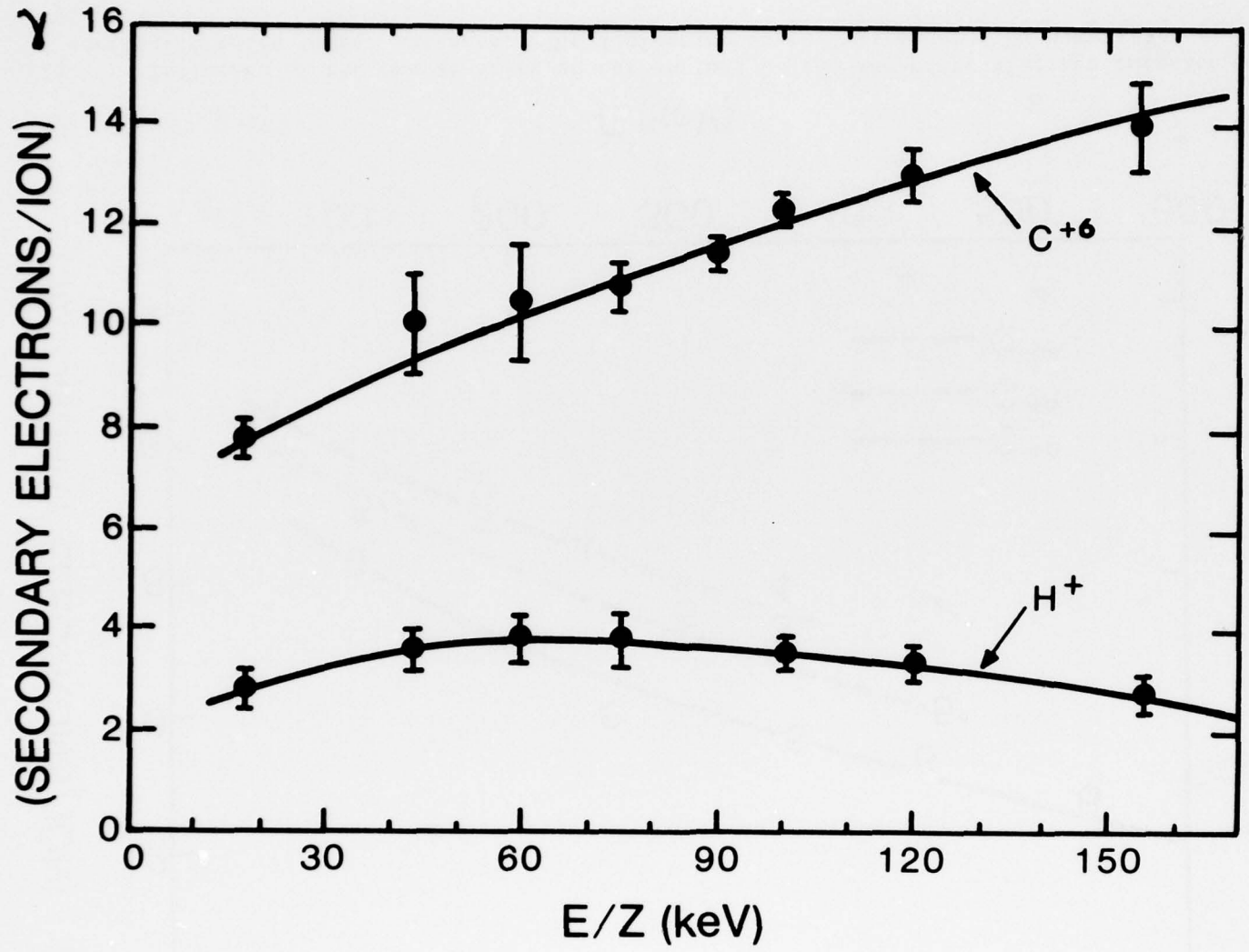


Fig. 3 - Secondary electron emission coefficients for C^{+6} and H^{+} ions incident on "gassy" copper surfaces as a function of ion energy.

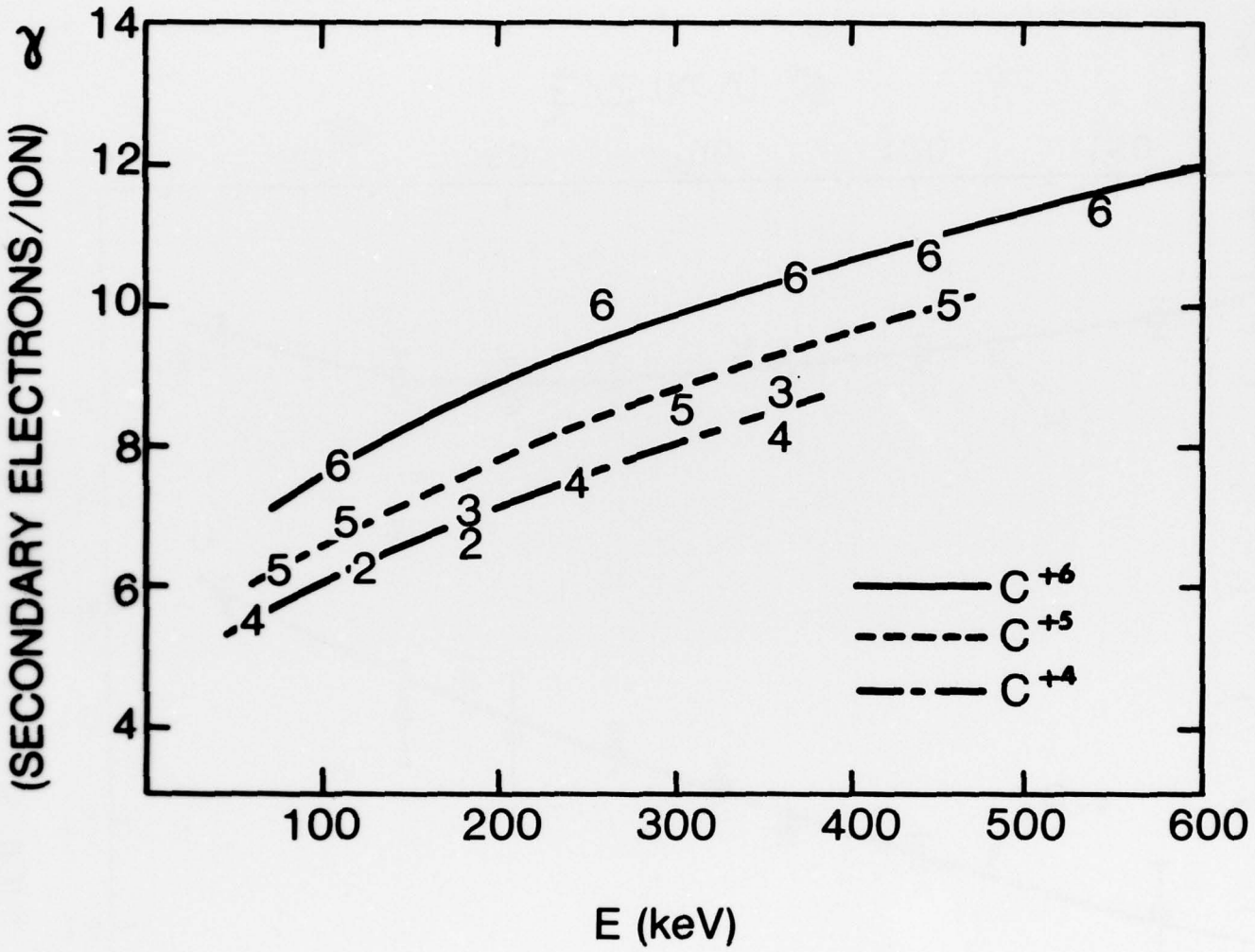


Fig. 4 - Influence of the charge state of carbon ions on the secondary electron emission coefficients for copper surfaces. The ionization state Z is denoted by numerals.

DEPARTMENT OF THE NAVY

NAVAL RESEARCH LABORATORY
Washington, D.C. 20375

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300
Third Class Mail

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DoD-316